

OUR ASTRONOMICAL COLUMN.

ASTRONOMICAL OCCURRENCES IN MAY:—

- May 2-6. Meteoric shower before sunrise from Aquarius.
 4. Tuttle's comet in perihelion.
 8. 11h. 6m. Minimum of Algol (β Persei).
 13. 8h. 47m. to 10h. 12m. Transit of Jupiter's Sat. III.
 16. Swift's comet closely S.W. of α Andromedæ (mag. 3.8).
 20. 12h. 5m. to 13h. 36m. Transit of Jupiter's Sat. III.
 24. 10h. 15m. to 11h. 25m. Occultation of B.A.C. 5254 (mag. 5.4) by the moon.
 26. 11h. 39m. to 12h. 39m. Occultation of 7 Sagittarii (mag. 5.4) by the moon.
 26. 12h. 3m. to 13h. 15m. Occultation of 9 Sagittarii (mag. 5.7) by the moon.
 27. 2h. Uranus in opposition to the sun.

TUTTLE'S COMET (1899 *b*).—The following positions are continued from the ephemeris by Herr J. Rahts in *Astr. Nach.* (Bd. 149, No. 3555):—

Ephemeris for 12h. Berlin Mean Time.

1899.	R.A.	Decl.	Br.
	h. m. s.	° ' "	
April 27 ...	4 32 53.4	+ 13 27 35	1.86
28 ...	36 20.6	12 59 33	
29 ...	39 47.2	12 31 20	
30 ...	43 13.3	12 2 56	1.89
May 1 ...	46 38.9	11 34 21	
2 ...	50 4.0	11 5 35	
3 ...	53 28.8	10 36 39	
4 ...	4 56 53.1	+ 10 7 33	1.90

TEMPEL'S COMET (1873 II.).—The following search ephemeris is given by M. L. Schulhof in *Astr. Nach.* (Bd. 149, No. 3554):—

Ephemeris for 12h. Paris Mean Time.

1899.	R.A.	Decl.	Br.
	h. m. s.	° ' "	
April 27 ...	18 36 50.4	- 5 13 22	0.370
28 ...	38 35.2	5 8 45	
29 ...	40 19.6	5 4 11	
30 ...	42 3.8	4 59 39	0.405
May 1 ...	43 47.6	4 55 11	
2 ...	45 31.1	4 50 46	
3 ...	47 14.2	4 46 25	
4 ...	18 48 57.0	- 4 42 8	0.460

DOUBLE-STAR CATALOGUE.—*Astr. Nach.* (Bd. 149, Nos. 3557 and 3558) contain a catalogue of 132 new double-stars which have been discovered by Prof. G. W. Hough, with the 18½-inch refractor of the Dearborn Observatory, Illinois, U.S.A. This is the fourth catalogue of new double-stars issued from the same observatory, the total number now reaching 622. The measures have been made during the period 1894 to 1897, each pair having been measured on two or more nights. Magnifying powers of 390 and 925 have been most frequently employed. It is noted that one of the stars, No. 580 in the catalogue, is probably a binary, successive measures having indicated motion between the components. This star is Lalande 37881, and its position for 1880 is R.A. 19h. 47m. 19s.; Decl. + 22° 9'. The change of position angle, on which the probability of its being a binary is based, is shown in the following table:—

Date.	Position angle.	Distance.	Magnitudes.
1895.76 ...	267.6	0".65	8—8.1
1897.62 ...	276.0	0".68	8—8.2

LAW OF TEMPERATURE IN GASEOUS BODIES.—The *Astronomical Journal* (No. 459) contains some further criticisms on Dr. See's article on "The Sun's Heat" (*A. J.*, No. 455) by Mr. C. M. Woodward, of Washington University. The points he brings forward are as follows:—

(1) Dr. See assumed his hypothetical gaseous globe to have a definite boundary, but there is no good reason to suppose that a pure gas, unrestrained save by the mutual attraction of its particles, has a definite limiting surface.

(2) The assumption that the pressure at R_0 is directly

measured by the weight of an element of mass is wrong; it is the variation in the pressure which is measured by the weight.

(3) Instead of the intensity of pressure varying *inversely* as the fourth power of the radius, as given by Dr. See, it really varies *inversely* as the square, or $P = \frac{A}{R^2}$.

(4) The final derivation of the formula $T = \frac{K}{R}$ is false, because the value of P , by which it is determined, is wrong. "Dr. See appears to forget that when the volume of a given gas is fixed by other considerations, the pressure is independent of the force of gravity. He leaves the question of temperature still unsolved. Instead of finding the temperature from the pressure, the temperature is to be determined by the principle that the change of temperature during contraction must be such as to render the force of mutual attraction sufficient to do the work of compression. For a solution of that problem, I beg leave to refer to my paper read before the Saint Louis Academy of Science, March 20, 1899."

RETURN OF HOLMES' COMET (1892 III.).—Mr. H. J. Zwiers gives in *Astr. Nach.* (Bd. 149, No. 3553) a detailed ephemeris for the expected return of this comet, which he calculates will pass perihelion on April 27. This not being quite certain, he also gives the positions corresponding to perihelion passages on April 19 and May 5. We append the positions for $T = \text{April } 27.6651$:—

Ephemeris for 12h. G.M.T.

1899.	R.A.	Decl.	Br.
	h. m. s.	° ' "	
April 28 ...	23 59 25.3	+ 4 0 15	0.0272
30 ...	0 3 0.8	4 37 29	
May 2 ...	6 35.7	5 14 44	
4 ...	10 10.1	5 52 1	0.0280
6 ...	13 43.8	6 29 19	
8 ...	17 17.0	7 6 37	
10 ...	20 49.5	7 43 54	
12 ...	24 21.4	8 21 11	0.0290
14 ...	27 52.7	8 58 25	
16 ...	31 23.3	9 35 39	
18 ...	0 34 53.2	+ 10 12 50	0.0298

THE THEORY OF THE RAINBOW.

MOST text-books still explain the rainbow phenomena with the aid of Descartes' "effective" rays. This explanation concerns only the principal and the secondary bows; it does not take notice of the supplementary bows, nor of the fact that the colours, their intensity, breadth, and sequence vary greatly with the size of the raindrops. That the rainbows are interference phenomena, was recognised by Young. Their correct theory is contained in Airy's "Intensity of Light in the Neighbourhood of a Caustic" (*Trans. Cam. Phil. Soc.*, vi. p. 379; viii. p. 595, 1838 and 1848). The intensity depends upon an infinite integral, which Airy first attempted to compute by quadratures. Stokes found a more convenient form for his integral. The theory was first verified by W. Hallows Miller in 1871; later by Boitel, Mascart, and others. In 1896, Prof. J. M. Pernter, then at Innsbruck, now director of the Central Station for Meteorology and Earth Magnetism at Vienna, presented a long paper on the colours of the rainbow and the white rainbow to the Vienna Academy (*Wien. Akad. Ber.*, 106, ii. a, p. 137, 1897). The paper involved very laborious calculations and experiments, and dealt fully with the influence of the size of the raindrops; it was referred to in *NATURE*, January 27, 1898. In the Jubilee number of the *Zeitschrift für österreichische Gymnasien*, December 1898, Pernter has now made an attempt to render Airy's theory intelligible to the pupils of secondary schools.

The importance of the angle of minimum deviation is explained with the help of the diagram (Fig. 1). Not to complicate the figure, the rays are all supposed to correspond approximately to Fraunhofer's line C in the red-orange. With increasing angle of incidence, the deflection of the refracted ray from its original direction becomes greater and greater, until a maximum is reached (the dotted ray); on further increasing the angle of incidence, the deviation decreases again.

That this is so, is shown in tables giving angles of incidence, refraction, and the resulting final deviation, and is further explained by a simple trigonometrical deduction. The reflected and refracted rays emerge, not parallel to one another, but divergent or convergent. The limiting ray of minimum deviation, and the rays in its immediate neighbourhood and approximately parallel to it, would be the "efficient" rays of Descartes. They have their significance, though not that which Descartes ascribed to them. For the C rays, this angle (which corresponds to an angle of incidence of $59^{\circ} 24'$) is $42^{\circ} 4'$; that is to say, the red-orange arc of the primary bow is seen under that angle. Multiple reflection within the raindrops renders an infinite number of other such limiting rays possible. The emerging rays would emanate from various quadrants. We should hence see bows, not only when standing with our backs to the sun, but also when a cloud is between our eyes and the sun (e.g. in the case of three and four internal reflections). The direct sunlight would prevent our seeing those bows, but they can be observed and shown in class-rooms when we let the light fall on cylindrical glass rods after Babinet's fashion. With cylinders instead of spherical drops, we see, of course, a series of vertical coloured bands, arranged in a horizontal line, instead of arcs. Miller, experimenting with water streams, measured thirty such monochromatic bands. Pernter describes a simpler arrangement, and calculates, in his popular treatise, the angles of minimum deviation for fifteen bows, both for water and glass. Experimenting with white light and water streams, 1 mm. and less in diameter, he counted with 1 mm. drops one bow and twenty-four secondaries (supplementary bows) of beautiful colours (white in the twelfth, after which the sequence of the colours is reversed), and with drops of 0.5 mm. eleven bows and secondaries and some more bands of indistinct colour (white in the fifth).

We recognise from Fig. 1 that the emerging wave has not a straight front like the entering spherical wave AB, but a peculiarly curved front, represented in exaggerated curvature in Fig. 1a. Such a wave must give rise to interference phenomena, and all the rainbows, not only the supplementary (or so-called spurious) bows, are really diffraction phenomena of a peculiar kind. That part of the wave-front which is nearest to the ray of minimum deviation might be called the effective wave-front. In order to arrive at an equation for that part, Pernter starts from Wirtinger's consideration that, if s_1 , s_2 , and s_3 are the paths of a ray, in the air, in the water and again in the air, reckoned between the entering and the emerging wave-fronts, and c_1 and c_2 the velocities of light in air and in water, then $\frac{s_1}{c_1} + \frac{s_2}{c_2} + \frac{s_3}{c_1} = \text{const.}$ for all rays of that wave. The constant can be chosen at will; he takes the value $\frac{a}{c_1}$, in which a is the radius of

the drop. Under the assumption that the curve consists of two spherical arcs, one concave, the other convex, Pernter then calculates the phase difference after Mascart. As regards the amplitude, however, of his intensity equation, he has to refer back to Airy; but he succeeds in showing that each colour of the rainbow consists of an infinite number of coloured rings of decreasing intensity, separated by rings of intensity 0. Pernter objects to the term "spurious" rainbows, since they are as much rainbows as the ordinary bows; his own terms, Hauptbogen, Nebenbogen, secundäre Bogen (principal bow, by-bow, secondary bows) are not suitable for literal translation. When we replace the prism of a spectroscope by a glass rod, 2 mm. in diameter, and set the telescope under $22^{\circ} 51'$ (principal

bow for glass), we see a series of red bands as mentioned. If this angle is not convenient, we adjust the instrument for one of the other bows. The first is by far the brightest; after the eighth maximum the intensity diminishes very slowly; Airy's original curve brings this out very clearly. Replacing the rod by one, less than 1 mm. in diameter, we notice that the colours are different and less bright; the blue, absent in the first experiment, is prominent, and all the bands are broader than before. Smaller raindrops give broader bows, but, owing to their diminished intensity, their number appears smaller. Fig. 2 is Pernter's colour curve for raindrops 0.5 mm. in diameter. The size of the actual raindrops lies, for our latitudes, between 0.05 and 2 or 3 mm. diameter. The fog-bow is produced by the sun when shining on the water globules, 0.05 mm. and less in diameter, of fine mists. We notice that we get real white in the bow by superposition of the colours. This is possible for drops of all sizes, and must occur with very small drops. The sequence of the fog-bow colours is: very faint yellow, whitish yellow, bright white, whitish violet; colourless gap; then (secondary bows) faint whitish blue, white, whitish red. To imitate these mists, Pernter fixed a glass tube, 0.5 mm. in diameter, in a lead pipe connected with the high-pressure water mains, and directed the jet against a metallic plate; the mist thus produced consisted of drops 0.0106 mm. in diameter. McConnell (*Phil. Mag.*, 29, p. 453, 1890), who made calculations for raindrops of certain sizes in

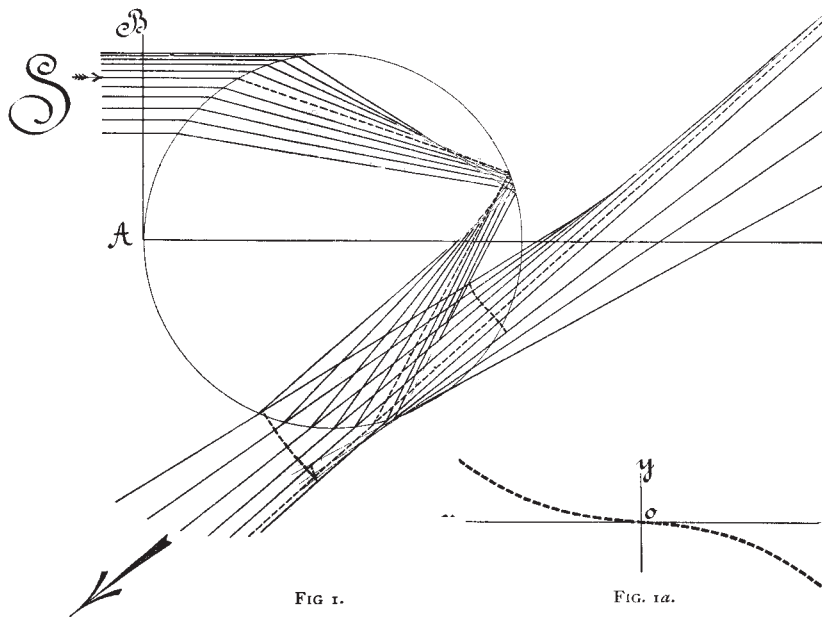


FIG. 1.

FIG. 1a.

1890, describes eighteen fog-bows, observed by Osmond in 1886-87 on Ben Nevis; of these, ten were double. Exact measurements of rainbows are exceedingly scarce. Pernter differs from McConnell as regards the border colours of fog-bows; he also doubts that the pale colour of fog-bows can be due to the uneven sizes of the drops, because the accompanying phenomena, glories, require homogeneous conditions. But dilution with white light, of course, makes all colours appear whitish.

Pernter's conclusions are interesting to meteorologists. The greater the drops, the more secondary bows. Bright pink and green, without blue, indicate drops from 1 to 2 mm. in diameter; intense red occurs with big drops only, but the maximum intensity is really in the violet. Drops of 0.5 mm. give secondaries consisting of green and violet (and also blue, which, however, is masked by contrast), immediately joining the principal bow. Yellow in the secondary would mean drops of 0.3 mm. and, if there are separating gaps, of 0.2 mm. Drops of diameters between 0.17 and 0.4 mm. show the greatest variety of colours, also in the secondary bows; but real red is absent. When we notice five and more secondaries of striking breadth

without white and without gaps, we have probably drops of 0.1 mm.; in smaller drops, gaps and white make their appearance. A real white bow with yellow or orange and blue margins requires drops of not more than 0.05 mm. Moonbows appear white owing to their feeble intensity. A small change in the size of big drops does not much matter. These

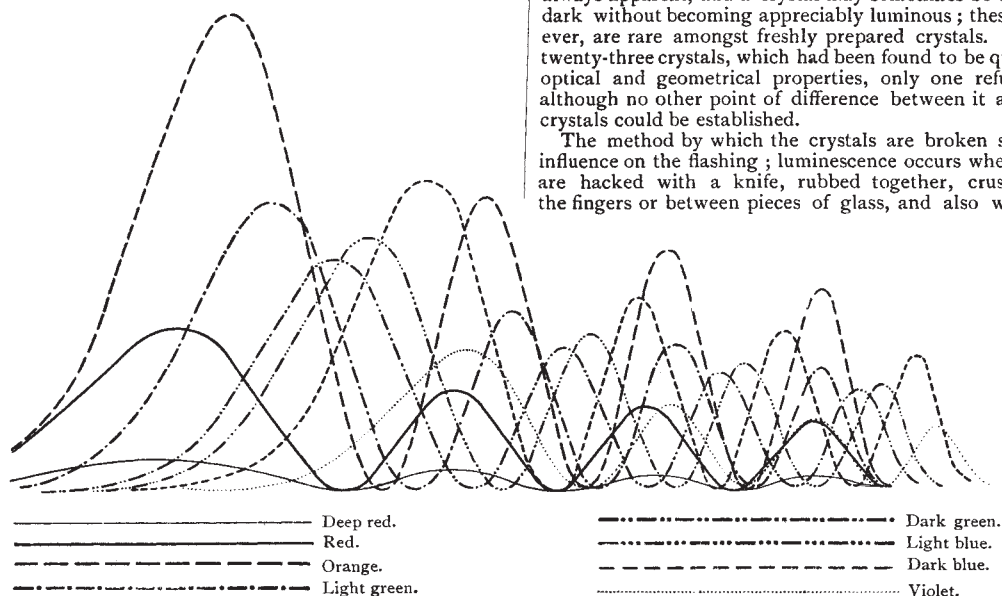


FIG. 2.

statements are based upon calculations and laboratory experiments; a confirmation by actual observations is hardly possible, since we cannot measure the size of the raindrops that produce the rainbows whose colours we are studying. H. B.

ON TRIBOLUMINESCENCE.

THE name triboluminescence has been applied by E. Wiedemann to an emission of light not due to rise of temperature which occurs on crushing certain substances.

It has long been known that on tearing cleavage sheets of mica apart, or on crushing crystals of cane sugar, light is given out; and during the last few months attention has again been drawn to this curious phenomenon by a paper read before the British Association by Mr. J. Burke, on the luminosity produced by striking sugar crystals (*NATURE*, vol. lviii. p. 533), and by Mr. T. Steel's letter to *NATURE* (vol. lix. p. 295) on the same subject. A brief account of other work done on the subject of triboluminescence during recent years may therefore be of interest.

Some years ago I contributed a paper to the Chemical Society (*Trans. Chem. Soc.*, 1895, 985) on orthobenzoisulphinide $C_6H_4 \begin{smallmatrix} SO_2 \\ \diagup \quad \diagdown \\ CO \end{smallmatrix} NH$, the substance known commonly as saccharin, and which is now largely used as a substitute for sugar when the use of the latter is considered undesirable upon medical or other grounds. I showed that commercial saccharin crystallises, on spontaneous evaporation of its solution in acetone, in large, transparent, monosymmetric crystals having the geometrical constants: $a : b : c = 2.7867 : 1 : 1.7187$, $\beta = 76^\circ 8' 30''$. On breaking or crushing the freshly prepared crystals, they emit a very vivid, bluish-white light, which, however, is only of momentary duration. This flashing or phosphorescence of the crystals is very brilliant, and is quite noticeable even in a well-illuminated room. The luminescence was, in fact, first noticed whilst the crystals were being manipulated in the full glare of an incandescent gas lamp. The phosphorescence may be well shown on a small scale by pulverising a crystal between two microscope slides, and on a larger scale by vigorously shaking a bottle of the crystals in a dark room; on grinding a quantity of the material in a glass mortar in the dark, an almost con-

tinuous, though rather fainter, luminescence is observed. On closely watching large transparent crystals whilst crushing them, the illumination appears to consist of a glow which pervades the whole crystal just as it breaks, and then immediately disappears; the emission of light consequently occupies so short a time as to appear instantaneous. The luminescence is not always apparent, and a crystal may sometimes be crushed in the dark without becoming appreciably luminous; these cases, however, are rare amongst freshly prepared crystals. On crushing twenty-three crystals, which had been found to be quite normal in optical and geometrical properties, only one refused to flash, although no other point of difference between it and the other crystals could be established.

The method by which the crystals are broken seems without influence on the flashing; luminescence occurs when the crystals are hacked with a knife, rubbed together, crushed between the fingers or between pieces of glass, and also when they are

caused to crack by rapid heating, either in the air or in the acetone mother liquor from which they crystallise. There seems to be no particular plane in the crystal parallel to which breaking occurs without luminescence; no matter how carefully a crystal is cleaved along the very perfect cleavage on the pinacoid {100}, so that parting only occurs parallel to the cleavage plane, and with a minimum of shock, vivid luminescence always occurs; and on carefully cutting the crystals in directions perpendicular to the cleavage, so that very little parting occurs along this plane, a brilliant flash almost invariably results.

An exhaustive examination of the properties of the crystals was made, in order to allow of some cause being assigned to this peculiar phenomenon; it was at first thought that the crystals might be hemimorphic or hemihedral, and that the luminescence might be in some way related to the polar properties inseparable from hemimorphism. No positive evidence was, however, obtained in this direction.

Crystals of orthobenzoisulphinide, obtained by other methods than the above, showed no triboluminescence. The substance on heating sublimes in long glistening needles, which are morphologically and optically identical with the crystals deposited from acetone, but show no triboluminescence.

After the publication of the paper referred to, Luigi Brugnatelli (*Zeits. f. Krystallographie*, 1897, **27**, 78) gave particulars of several similar cases found by him amongst derivatives of santonin prepared by Amerigo Andreocci (*Atti d. R. Accad. Linc.*, 1895, [5a], **2**, 28). The monosymmetric crystals of

ethylisodesmotroposantonin, $C_{12}H_{13}(OEt) \begin{smallmatrix} O.C:O \\ | \\ CHMe \end{smallmatrix}$ emit a yellow luminescence when crushed; the monosymmetric crystals of the enantiomorphously related dextro- and lævo-ethylsantonite, $C_{12}H_{13}(OH)CHMe.CO.OEt$, and the monosymmetric crystals of lævodisotroposantonous acid, $C_{12}H_{13}(OH)CHMe.CO.OH$, all give a yellowish-green triboluminescence. Lævoethylisotroposantonous acid $C_{12}H_{13}(OEt)CHMe.CO.OH$, crystallises in hemihedral anorthic crystals, which when crushed glow with a beautiful emerald-green light.

Crystals of saccharin have also been examined by W. Arnold (*Zeits. f. Kryst.*, 1896, **27**, 92), who describes their triboluminescence as "stark," and states that that of crystallised hippuric acid $C_6H_5.CO.NH.CH_2.CO.OH$, is "sehr stark."